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Study of decreasing the driving voltage of HOPFED

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Abstract

Hop spacer field emission display (HOPFED) has several advantages like the well use of secondary electron and the outstanding focus effect. To decrease the manufacture cost of HOPFED, the driving voltage has to be small enough. In this paper, an improved structure has been proposed to decrease the driving voltage.

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Keywords: Secondary electron; Driving voltage; Field emission electron source

1. Introduction

Compared to CRTs, Field Emission Displays (FED) potentially have a low cost and smaller depth. However, there are still some technical issues that prevent the mass production of FED. In order to become a successful product, the FED has to reach good picture quality and low cost. HOPFED is a new structure based on the secondary electrons emission [1]. With modulation of the energy of the primary electrons, the number of the electrons passing through the hop aperture can be controlled. In a matrix display device, a large fraction of the set cost is covered by the driving electronics. Therefore, a low driving voltage has to be applied to decrease the cost [2].

In this paper, the driving characteristic of a HOPFED is simulated with a software based on

Monte-Carlo method. Then, an improved structure has been proposed, and its emission character is also simulated. From the comparison of the simulation results, it can be seen that the structure proposed in this paper can reduce the driving voltage significantly.

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2. Simulation of the basic model

A conventional structure of HOPFED is shown in Fig. l.

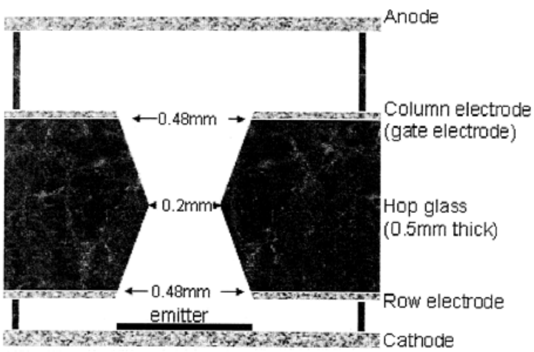


Fig. 1. The basic structure and its parameters.

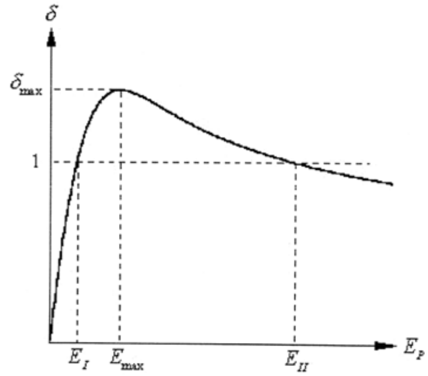


Fig.2. The curve of secondary electrons coefficient versus landing energy of primary. In the figure, E_I and E_{II} are the lowest energy and highest energy at which the secondary electrons yield becomes one.

Because MgO is a kind of high secondary electron emission material, the inside wall of the HOP aperture is coated with MgO layer to increase the number of the secondary electrons. The typical relationship between secondary electron emission coefficient and the energy of primary electron is shown in Fig. 2.

In Fig. l, a fixed negative voltage is applied on the cathode and 0V is applied on the row electrode when emission is turned on. From the numerical simulation, the gate driving characteristic can be obtained. The curve of the normalized current density versus the gate voltage is shown in Fig. 3.

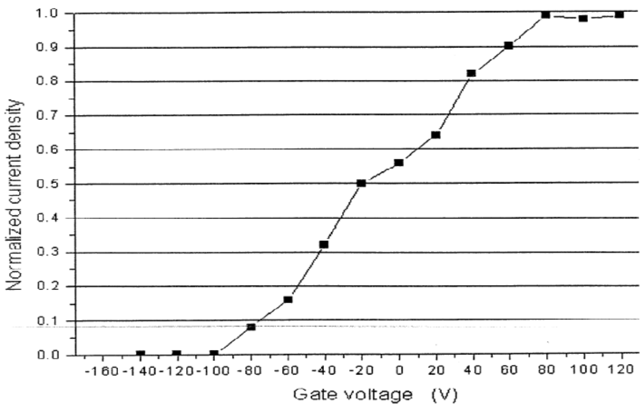


Fig. 3. The curve of the normalized current density versus the gate voltage.

As shown in Fig. 2, the gate driving voltage swings from −100V to +80V, so the gate driving characteristic is not good enough. This is due to the thickness of the Hop glass. For leading to full emission, a sufficiently high voltage must applied to the row electrode to get high energy of electrons. Because the Hop glass is too thick, the V_{col} can not control the energy of the primary electrons sensitively enough. Also, the high anode voltage will penetrate into the Hop aperture. This will pull out many electrons containing primary and secondary electrons easily. Therefore, the column driving voltage is much higher than the row voltage.

3. Simulation of an improved structure

To decrease the modulation voltage further, we proposed a new structure as shown in Fig. 4. Compared with the structure in Fig. 2, an additional column is fabricated upon the row electrode. There is a dielectric layer to separate the row electrode and the column add electrode, and the thickness of the dielectric layer is 30 μm in the simulation. The voltage applied on this electrode is the same as that applied on the column electrode.

Fig. 5 gives the gate driving characteristic. The gate driving voltage swings from −40V to +20V, which has greatly improved compared with the basic structure in Fig. 2.

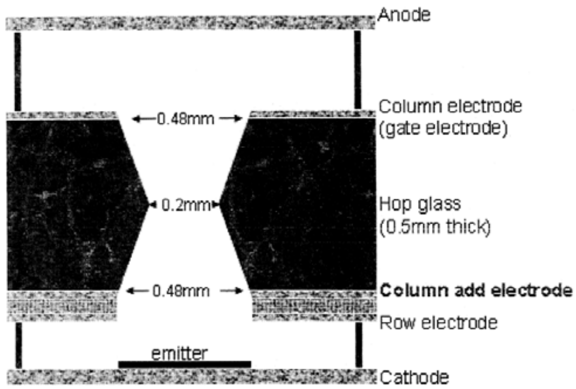


Fig. 4. A new structure to decrease the gate driving voltage.

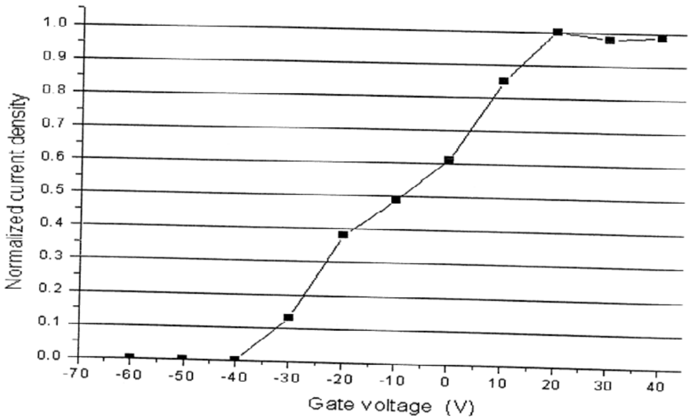
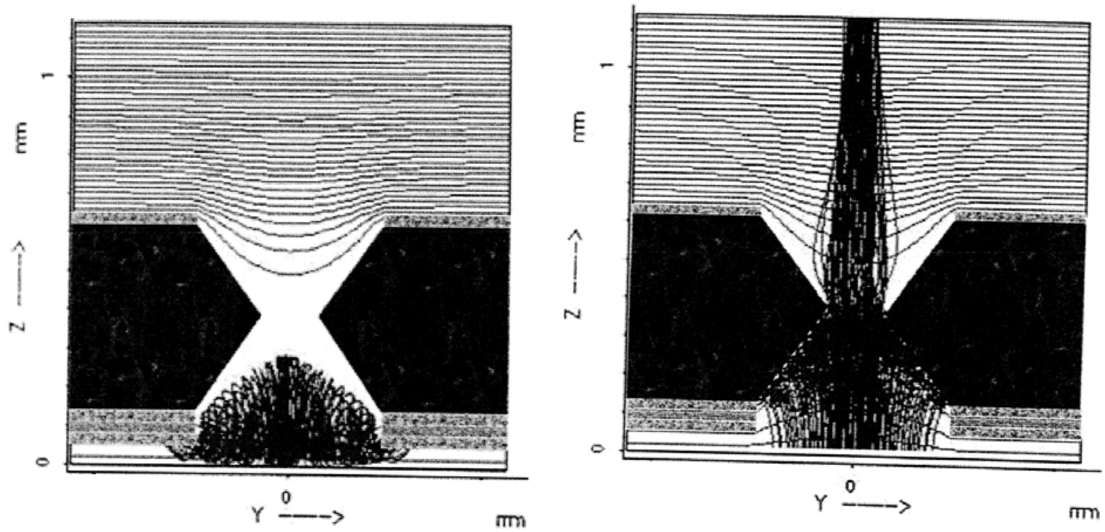


Fig. 5. The curve of the normalized current density versus the gate voltage.

As shown in the simulation results, the additional column electrode is used to reduce the velocity of electron when the V_{col} is low If we compare Fig. 5 with Fig. 3, we can see that the turn off voltage changed from −100V to +40V. Because the additional column electrode is near the row electrode and located under the Hop glass, a relatively low voltage applied on it will greatly decrease the energy of the primary electrons. Fig. 6 shows the electron trajectories with different driving voltages.



(a) (b)

Fig.6. (a) shows the trajectory of the electrons when the gate voltage is –40V.
(b) shows the trajectory of the electrons when the gate voltage is +20V.

As we can see from Fig. 6(a), when V_{col} is –40V, the primary electrons will not land on the inside wall of the Hop aperture. When V_{col} is +20V, the current density reaches its maximum value, and most of the electrons landing on the anode are secondary electrons.

4. Conclusion

In this paper, we analysed the driving performance of a conventional HOPFED. To decrease the driving voltage, an additional column is fabricated upon on the ground electrode. As the simulation results show, the column driving voltage can be lower than 60V. Therefore the structure proposed in this paper can significantly decrease the driving voltage of HOPFED.

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